

THE ECOLOGY OF THE CENTRAL COASTAL AREA OF NEW SOUTH WALES. I.

THE ENVIRONMENT AND GENERAL FEATURES OF THE VEGETATION.

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(Plates xvi-xvii; six Text-figures.)

[Read 24th November, 1937.]

The area considered in this series of papers is the central coastal plateau region east of the main divide extending to the edge of the Hunter Valley in the north, to Cox's River in the west and to the Lower Shoalhaven Valley in the south. It includes the County of Cumberland, and the adjoining portions of the Counties of Northumberland, Hunter, Cook and Camden (Long. 150-151.5, Lat. 33-35 approx.).

Two plant-formations occur in this area: Eucalyptus forest and sub-tropical rain-forest. The endemic Australian and Indo-Malayan floristic elements correspond respectively to these formations (Maiden, 1914). Eucalyptus forest is the dominant formation not only of the central coast but of the whole coastal area and adjacent highlands¹ of New South Wales. It shows several important phases which are due to the variation in soils, climatic factors and physiographic habitats.

Rain-forest is limited to the coastal belt where there is a high rainfall; there it occurs in scattered patches on good soil, usually in areas sheltered from winds and extreme insolation.

In this series of papers a description is given of the structure and composition of these coastal Eucalyptus forests, especially those typical of the two characteristic geological formations of the area: Hawkesbury Sandstone and Wianamatta Shale. An attempt is made to classify the Eucalyptus forests on the basis of associations (Clements, 1916, 1936) within the formation. The successional phases of the sandstone vegetation are also discussed.

The Mt. Wilson forests, which form part of the Eucalyptus forest formation occurring in this area, have been described in detail by Petrie (1925), and McLuckie and Petrie (1926); Davis (1936) has outlined the forest communities occurring on a portion of the Illawarra (South Coast). No other detailed forest ecology has been done in this area, but reference must be made to the general accounts by Robertson (1926) and Osborn (1932). A number of general floristic accounts of the sandstone flora, chiefly in the Sydney District, have also been published. Reference will be made to these in later publications.

¹ On the western slopes of the Dividing Range, this formation gives place to a more open type of vegetation known as savannah woodland.

THE ENVIRONMENT.

*Geology.*² (See Text-fig. 1.)

With the exception of some volcanic rocks, chiefly basalts, and some deposits of river alluvium and wind-blown sand, the geological formations occurring in the area are sedimentary. The sequence of the sedimentary series is as follows:

Triassic	{	Wianamatta Shales.
		Hawkesbury Sandstones.
		Narrabeen Shales and Sandstones.
Permian	{	Upper Coal Measures
		(Newcastle-Bulli-Lithgow).
		Upper Marine Series.

Centring about Sydney the Permian rocks are in the form of a great basin, whose rim appears at the surface on the north, west and south of the area, the eastern rim being submerged by the ocean (Text-fig. 1). The individual formations of the Triassic System lie conformably above the Permian Basin. These sedimentary strata are generally horizontal. Most of the beds are thickest in the vicinity of Sydney or along the adjacent coastline.

The lower beds of the Upper Marine Series consist chiefly of siliceous conglomerates and coarse sandstones, with a small amount of shaly and fine-grained sandstones. The upper beds of this series comprise calcareous shales, sandstones and mudstones with tuffaceous material and lava flows which are particularly prominent in the coastal districts in the south of the area (Illawarra). The Upper Marine Series attains a thickness of several thousand feet in the south but becomes thinner at its western rim.

The Upper Coal Measures include sandstones, conglomerates, shales and cherty tuffs with coal seams. On the coastline (at Bulli) the coal-measures have a thickness of about 1,000 feet, which decreases to 400 feet in the west (Mt. Victoria and Lithgow).

Sandstones compose the greater part of the Narrabeen Series where it outcrops on its western rim (Blue Mts.), but along the coast shales and sandy shales are also important. The maximum thickness of the Narrabeen Beds on the coast is 1,740 feet, but this decreases to 300 feet in the west (Mt. Victoria). A very constant feature is the occurrence of tuffaceous chocolate shales, which form two conspicuous bands near the top of the series. They are often more than 100 feet

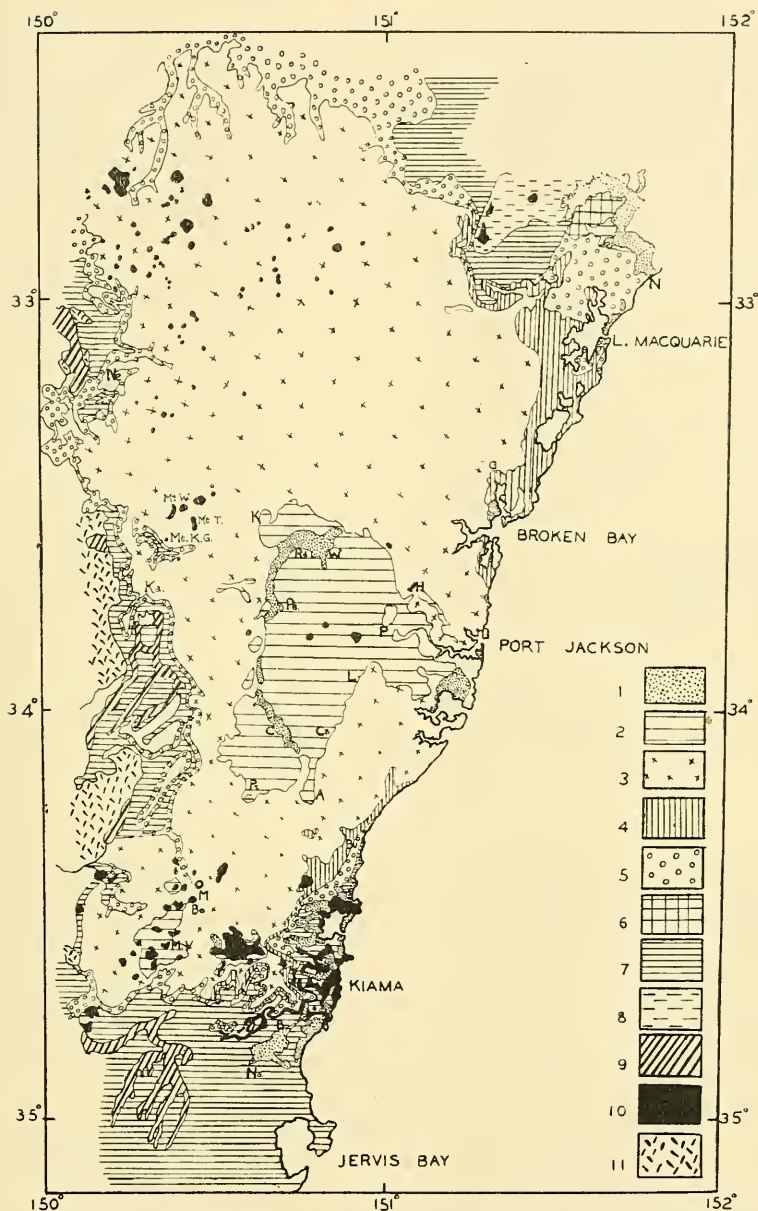
²In compiling these geological notes the following articles have been consulted: Willan (1923), Woolnough (1927), Handbook A.N.Z.A.A.S. (1932).

5. Upper Coal Measures	}	Permian.
6. Middle Coal Measures		
7. Upper Marine Series		
8. Lower Marine Series		
9. Quartzites, sandstones, shales, lime-stones, etc.	}	Devonian.

Igneous.

- | | |
|----------------------|--------------------------|
| 10. Mainly basalts. | Tertiary (principally). |
| 11. Mainly granites. | Permian to Pre-Cambrian. |

Towns referred to are: A, Appin; B, Berry; Bo, Bowral; Bu, Bulli; C, Camden; Ca, Campbelltown; G, Gosford; H, Hornsby; K, Kurrajong; Ka, Katoomba; L, Liverpool; M, Mittagong; MV, Moss Vale; N, Newcastle; Ne, Newnes; No, Nowra; P, Parramatta; Pe, Penrith; Pi, Picton; R, Richmond; W, Windsor.—Mt. W., Mt. Wilson; Mt. T., Mt. Tomah; Mt. K.G., Mt. King George.



Text-fig. 1.—Geological map of the central coastal area, adapted from the Geological Map of N.S.W., Dept. of Mines, 1914. Scale, 1" = 32 miles.

Sedimentary.

- | | |
|---|-----------------------------------|
| 1. Alluvial deposits and wind-blown sand. | Recent, Pleistocene and Tertiary. |
| 2. Wianamatta Series | } Triassic. |
| 3. Hawkesbury Sandstones | |
| 4. Narrabeen Series | |

thick on the coast but diminish towards the west, although still conspicuous in the cliffs of the Blue Mts.

The Hawkesbury Series, which is the most extensive, consists chiefly of siliceous sandstone with a few small lenticular beds of shale. The sandstone occurs in the form of massive jointed bands which weather into blocks. Bands of grit and conglomerate which occur in the sandstone become increasingly more important to the west. The Hawkesbury Sandstones attain a depth of 1,100 feet at Sydney, but in the west at Mt. Victoria the thickness is only 100 feet. Here, the thinning out of the beds has been accentuated by erosion.

The Wianamatta Series has been divided into two stages. The lower consists almost entirely of laminated shale which is carbonaceous and ferruginous near the base. Beds of a very calcareous sandstone form the upper stage. A maximum thickness of 1,000 feet is attained in the Camden district. These shales are easily weathered and have been eroded over a large area.

Some Pleistocene and recent river alluvials are found on the Sydney and coastal plains. There are also some fairly large areas of blown sand, derived chiefly from Hawkesbury Sandstones, which form dunes in the coastal areas.

In the vicinity of Sydney igneous rocks occur scattered as innumerable small intrusions, usually in the form of dykes. Several volcanic necks also occur. Larger intrusions occur at Prospect, Mt. Jellore (dolerite) and Mt. Gibraltar (syenite). Remnants of basalt flows which were once very extensive cap several physiographic residuals in the Blue Mts. and occur on the uplands in the vicinity of Bowral, Moss Vale, etc. All these igneous rocks are relics of the Pliocene volcanic epoch.

More extensive and important are the flows of trachy-andesites and trachy-basalts which are interbedded with the shales and sandstones of the Upper Marine Series. Other evidence of volcanic activity at this period is seen in the presence of basic tuffs and tuffy mudstones in the same series.

*Physiography.*³ (See Text-fig. 2.)

(1) General.

To the north, south and west of Sydney is a deeply dissected plateau region composed chiefly of Hawkesbury Sandstones. This encircles a central gently undulating low-lying area, the Sydney Plains, in which the underlying rocks are Wianamatta Shales. These plains are connected to the coast by an E-W strip of land which interrupts a precipitous coastline of sandstone headlands alternating with narrow beaches. This type of coastline, broken in several places by drowned river-valleys, characterizes the central part of the coast. To the north and south, a narrow undulating coastal plain gradually widens as the sandstone scarp recedes from the coastline.

The general physiographic features of the area are the result of a differential uplift in the Kosciusko Epoch⁴ which converted a late Tertiary peneplain into a plateau with a general upward slope on the west, but with two central depressions or troughs, due to lagging during the uplift or subsequent sagging. The present alignment of the coast is probably due to faulting and foundering of a coastal strip at a period later than that of the main uplift. This subsidence of the coast to the extent of 150-200 feet resulted in the drowning of several large river valleys.

³ This brief account of the physiography of the area is drawn largely from the A.N.Z.A.A.S. Handbook (1932).

⁴ About the close of the Pliocene Period.

This was followed by a more recent emergence of 15 feet. Erosion by undercutting of the sandstone was a further factor in determining the coastal physiography.

Some diversity in altitude occurs over the area (see Text-figs. 2, 3). The Sydney Plains, which have an average elevation of 100–200 feet, are bounded to the west by a steep monoclinical fold forming the edge of the Blue Mts. Plateau which rises from this scarp more gradually to a level of 3,500 feet on its western margin. On the west, the Blue Mts. Plateau is separated by the wide valley of Cox's River from the Jenolan Plateau which rises to over 4,000 feet.

On the north and south of Sydney, the land increases in elevation gradually. To the north, the "Hornsby Plateau" rises to an average elevation of 600–700 feet and is then interrupted by the steep foreshores of the drowned valley of the Hawkesbury River. North of this it gradually attains an elevation of 1,700–1,900 feet, terminating as a scarp overlooking the southern edge of the Hunter Valley. South of Sydney the coastal plateau, sometimes referred to as the Nepean Ramp, rises more gradually and increases in elevation from 500 feet to a maximum of 2,000 feet at Robertson in the south and Mittagong and Moss Vale in the south-west. The plateau in these districts is conveniently referred to as the Robertson and Moss Vale–Mittagong Plateaux. The southern boundary of this sandstone plateau is the northern edge of the Lower Shoalhaven Valley.

The areas to the north and south of the Blue Mts. attain an average elevation of 2,500 feet, and may be referred to as the Colo and Wollondilly regions. These plateau areas link up with the northern part of the Hornsby Plateau and the southern section of the Nepean Ramp to form a continuous semicircular plateau extending from the Hunter Valley west of the Sydney Plains to the Lower Shoalhaven.

It is generally accepted that the rivers of the coastal area were either brought into existence or rejuvenated from a mature or senile condition by the uplift. The stream-patterns in the central coastal area indicate a complex history which cannot be discussed here (see Handbook, 1932).

The Nepean is the largest river (see Text-fig. 2). It rises in the Nepean Ramp and flows in a northerly direction, but changes its course abruptly to the east and joins the sea as the Hawkesbury River. Several tributaries of the Nepean drain the Nepean Ramp. These are the Cataract, Cordeaux and Avon Rivers, whose steep gorges have been dammed. Other important tributaries of the Nepean are the Wollondilly and Cox's Rivers, which join the Nepean as the Warragamba River, and the Grose, Colo and Macdonald Rivers.

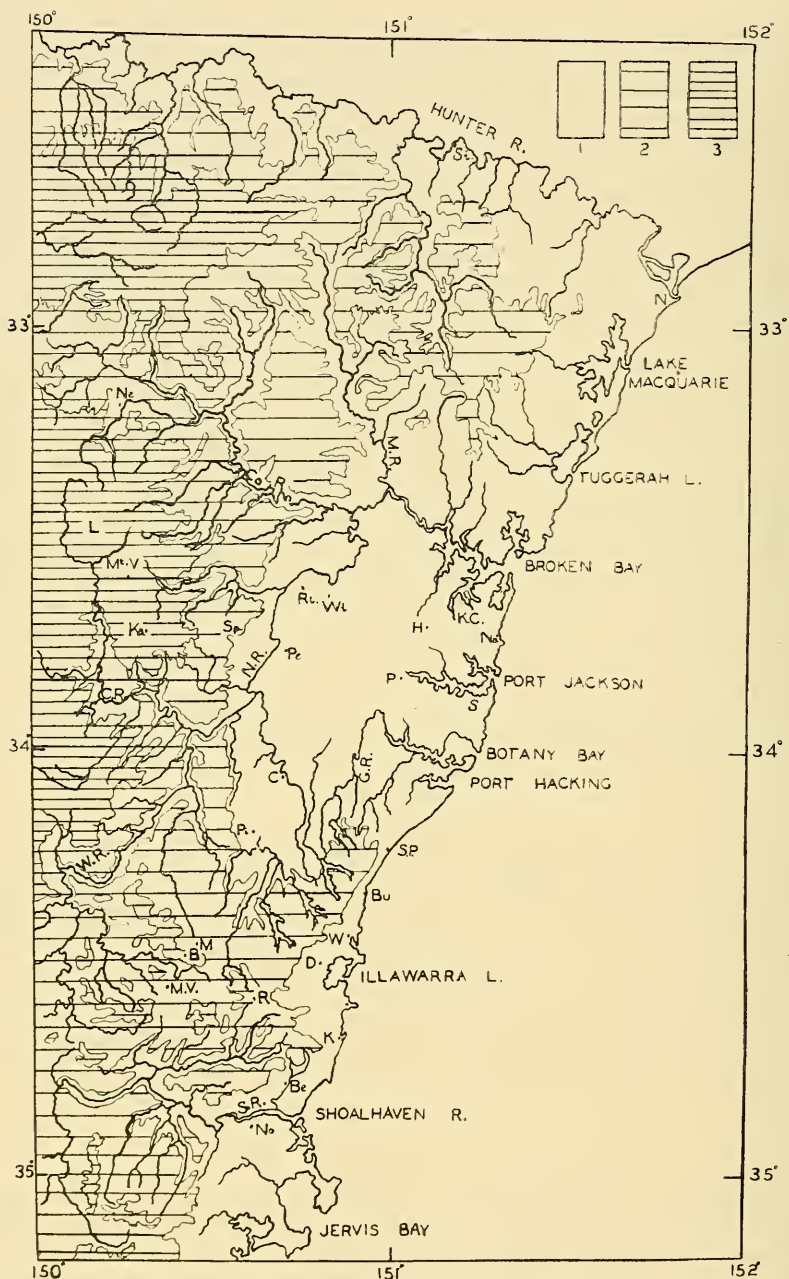
There are no rivers of any magnitude on the coast between the Hawkesbury and Shoalhaven. The most important of the smaller streams are the Port Hacking and George's Rivers. Tributaries of the Hawkesbury, such as the Berowra, Cowan, Mangrove and Mooney Mooney Creeks are of local importance only.

(2) Physiographical Regions.

(a) *The Sydney Plains.*

The plains are gently undulating, with many hills up to 300 feet. They are formed by two low-lying regions or depressions; one is a submeridional depression extending from about Windsor to Picton, bounded on the west by the monocline of the Blue Mts. (Pl. xvi, fig. 1), and on the east warping into the low coastal plateau. The other is an east-west trough which connects the submeridional depression to the coast between the drowned valleys of Port Jackson and Botany Bay, thus dividing the coastal uplands into the Hornsby Plateau and Nepean Ramp.





Text-fig. 2.—Relief map of the central coastal area, adapted from the 1:1,000,000 map. 1, below 1,000 feet; 2, 1,000-2,300 feet; 3, above 2,300 feet.

Towns referred to are: B, Bowral; Be, Berry; Bu, Bulli; C, Camden; D, Dapto; H, Hornsby; K, Kiama; Ka, Katoomba; K.C., Kuring-gai Chase; L, Lithgow; M, Mittagong; M.V., Moss Vale; Mt. V., Mt. Victoria; N, Newcastle; Na, Narrabeen; Ne, Newnes; No, Nowra; P, Parramatta; Pe, Penrith; Pi, Pictou; R, Robertson; Ri, Richmond; S, Sydney; Si, Singleton; Sp, Springwood; SP, Stanwell Park; W, Wollongong; Wi, Windsor.

Rivers referred to are C.R., Cox's River; Co.R., Colo R.; G.R., George's R.; M.R., Macdonald R.; N.R., Nepean R.; S.R., Shoalhaven R.; W.R., Wollondilly R.

The Wianamatta Shales are co-extensive with the Sydney Plains, the physiography of this area having enabled their preservation. Shallow shale outliers occurring on parts of the sandstone uplands (see Text-fig. 1) indicate that a more extensive distribution obtained before the uplift and that subsequent restriction of these shales is due to erosion. The beds of the upper stage of the Wianamatta Series are more resistant than the lower soft shales and persist as hills and ridges, the most outstanding of which is Razorback Ridge, near Camden.

Alluvial deposits occur along the Nepean and Hawkesbury Rivers within the Sydney Plains. These alluvials have probably been derived from the adjoining sandstone uplands.

(b) *The Sandstone Plateaux.*

The horizontal bedding and resistant nature of the Hawkesbury sandstones are responsible for the typical physiographic and scenic characteristics of the plateaux, such as flat-topped hills and divides, and steep gullies and gorges.

There is evidence of an uplifted peneplain in the generally even skyline. This is broken in the west by the pre-Pliocene peneplain residuals of the basalt-capped Mt. Hay, Mt. King George, Mt. Tomah and Mt. Wilson in the Blue Mts., and in the south by the igneous intrusions of Mts. Jellore and Gibraltar near Bowral, which are also more resistant to erosion.

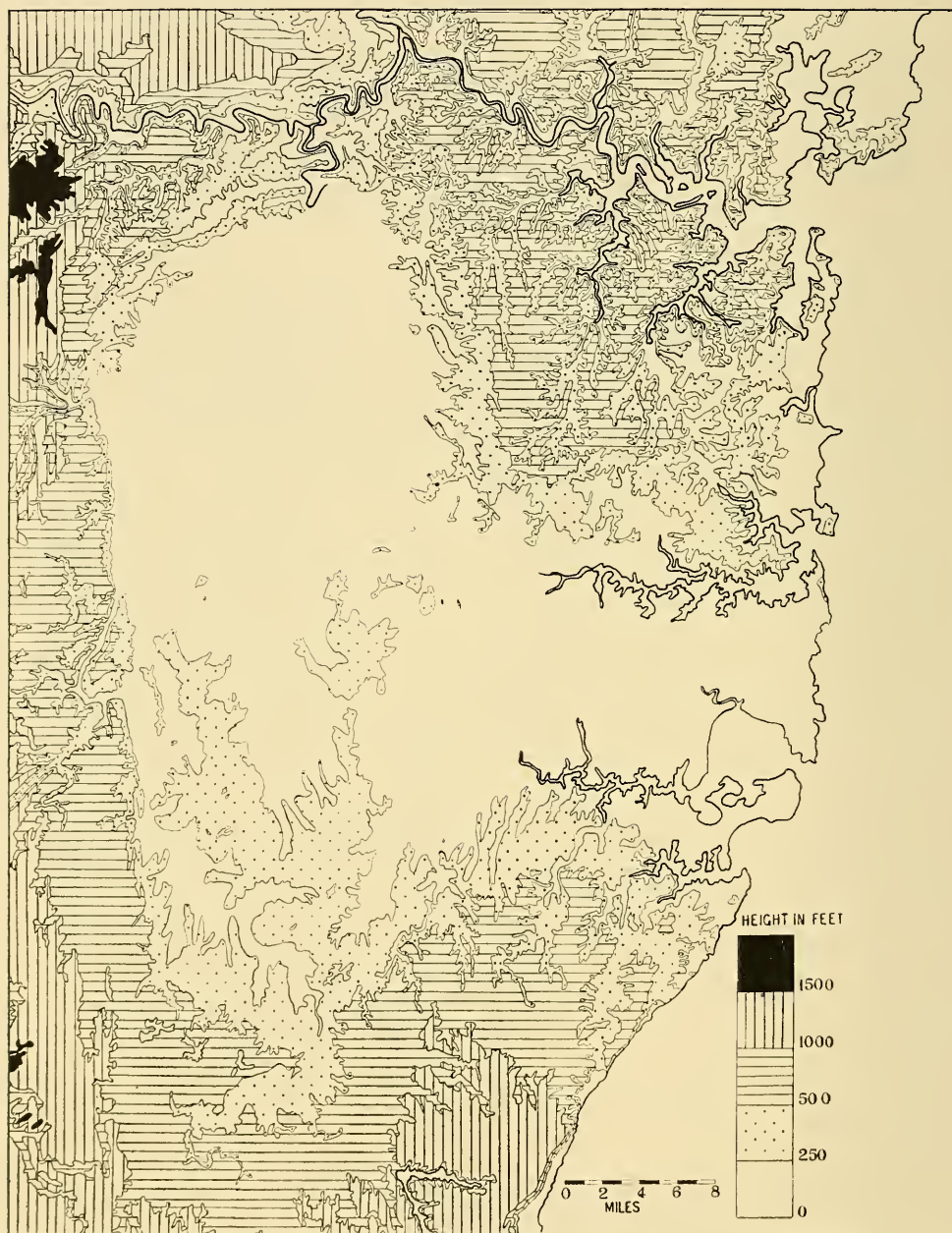
In the Blue Mts. deep gorges and canyons (Pl. xvi, fig. 2) dissect the plateau, the remnants of which form flat divides. Hawkesbury sandstone forms the surface of the plateau and, in the eastern section, extends to the bottom of the gorges. In the central and western sections, the rivers have cut through the sandstones of the Hawkesbury and Narrabeen Series to the soft shales of the Coal Measures. By erosion of the latter, and undercutting the upper sandstone layers, a type of canyon has been formed which is characteristic of the Blue Mts. Notable canyons are those of Cox's River and its tributaries, and the Grose River. In these canyons, whose walls are 3,000 feet high, the Hawkesbury and Narrabeen Beds constitute sheer cliffs, whilst steep talus slopes and wide level floors are formed by coal measures.

One peculiar physiographic feature in the Blue Mts. is that the streams not uncommonly occupy valleys which are too large for them, and in which erosion is now not active. This is satisfactorily explained only by an assumed lowering of the rainfall since Pleistocene time.

The Colo and Wollondilly plateau regions are characterized by juvenile gorges. Little is known of this uninhabited country, owing to its extremely rugged nature.

The northern upland area bordering the coast, the Hornsby Plateau (Pl. xvi, figs. 4, 3), is for the most part dissected by deep juvenile gorges separated by narrow divides. Owing to erosion, the Wianamatta Shales in the Hornsby Plateau are now restricted to the flat divide separating the deep valleys of Lane Cove River and Middle Harbour, and to a similar divide to the west which links up with the shales of the Sydney Plains. The Hawkesbury Sandstones are several hundred feet thick in this plateau, so that the Narrabeen Shales are exposed only in the deepest gorges.

The southern upland area, the Nepean Ramp, is not so dissected as the Hornsby Plateau. Broad, shallow, and sometimes swampy upland valleys are typical of the headwaters of the Cataract, Cordeaux and Avon rivers beyond the limits of rejuvenation. The Robertson Plateau, which is the southern extension of the Nepean Ramp, is a typical peneplain fringed by waterfalls and deep gullies. The Shoalhaven and Kangaroo Valleys, at the southern limit of the area, are typical canyons.



Text-fig. 3.—Relief map of the Sydney Plains and surrounding plateaux, reproduced by courtesy of Professor J. Macdonald Holmes of the Geography Dept., Sydney University. The estuaries shown from north to south are: Broken Bay, Port Jackson, Botany Bay and Port Hacking.

Although most of this southern plateau area is composed of sandstone, there is a fairly extensive capping of Wianamatta Shale in the vicinity of Moss Vale and Mittagong. In the same locality there are a number of remnants of basalt flows, particularly evident at Bowral, Moss Vale and Robertson.

(c) *The Coastal Plains.*

From Sydney, south to Stanwell Park and north almost to Broken Bay, the Narrabeen Series is below sea-level, so that Hawkesbury Sandstone cliffs extend to the sea. North and south of this area the Narrabeen Series outcrops, and at a further distance north and south, the Coal Measures also appear above sea-level. Where these softer strata outcrop, a coastal plain has been formed by erosion and subsequent undercutting of the overlying more resistant Hawkesbury Sandstone (Pl. xvi, fig. 6). This coastal plain widens and the sandstone scarp gradually recedes inland to the north and south as the sandstone capping of the plateau becomes thinner, and as progressively greater amounts of the underlying strata rise to the surface. This has enabled the coastal streams to erode farther back from the coast, and also to develop small flood-plains.

The central part of the coast-line, from Stanwell Park in the south to Broken Bay in the north, consists of short sand beaches alternating with headlands (Pl. xvi, fig. 5). The drowned river-valleys which interrupt this coastline are Port Hacking, Botany Bay, Port Jackson and Broken Bay. Of these, only the foreshores of Botany Bay and the southern shore of Port Jackson are low-lying. The estuaries of Broken Bay and Port Jackson extend far into the plateau, but all come under tidal influence for some distance up their estuaries.

South of Port Hacking the sandstone headlands are several hundred feet high and the beaches are very narrow (Pl. xvi, fig. 5). North of Port Jackson the sand beaches are much larger and lagoons usually occur behind them. There is a local development of a narrow coastal plain at Narrabeen and Newport, where the Narrabeen shales are exposed above sea-level. The irregular sandstone scarp of the Hornsby Plateau which skirts the coastline from Port Jackson to Broken Bay is about 400 feet high.

The coastal plain south of Stanwell Park, which is known as the Illawarra (Pl. xvi, fig. 7), and that north of Broken Bay gradually widen to approximately 10 miles in the vicinity of the Shoalhaven River in the south and to 15 miles at Lake Macquarie in the north. At Kiama, in the Illawarra, the plain is interrupted by the volcanic Saddleback Range which descends to the sea in very steep hills. The coastline bordering these plains also consists of headlands alternating here with long beaches, behind many of which are lagoons. Of these the most important are Lake Illawarra and Lake Macquarie.

North of Broken Bay, the Narrabeen Beds are responsible for the coastal plain and hill formations except in the vicinity of Lake Macquarie where the Coal Measures appear (see Text-fig. 1). On the other hand, the Illawarra is composed mainly of Coal Measures, Upper Marine Series including volcanic material, and river alluvials. Narrabeen Shales form the lower slopes of the northern section of the Illawarra scarp.

Soils.

Only a general survey of soil types is attempted here; later papers contain detailed data. In the following, field observations have been supplemented by tables of soil analyses, etc., from Jensen (1914).

In the central coastal area the soils are derived chiefly from the underlying formation *in situ*, small areas only being composed of re-distributed alluvial or wind-blown soil.

The three most extensive geological formations in this area weather to soils of very different texture; the Hawkesbury Sandstones yield sandy soils, the Wianamatta Shales heavy clay-loams, and the Narrabeen Shales rich loams. The volcanic soils are rich but very restricted.

For convenience, the soils are discussed under the following headings: sandstone, shale, igneous, alluvial and lateritic soils.

(1) Sandstone Soils.

According to the nature of the cementing material of the sandstone, the soils vary from poor sandy soils to fairly rich loams.

Siliceous sandstones, with aluminous or ferriferous clay as the cementing material, yield light-coloured sandy loams, poor in mineral plant food (see Table 1, lines 1 and 2). Such soils are derived from the Hawkesbury Sandstones, the conglomerates and sandstones of the lower beds of the Upper Marine Series, occurring in the vicinity of Nowra and Jervis Bay, and the sandstone and conglomerate beds in the Newcastle Coal Measures, in the north of the area (see Text-fig. 1). They are characterized by a low water-retaining capacity, and high capillarity. Where the sub-drainage and run-off are good, they are fairly warm soils, but where the ground-water level is high, the soils are cold and sour. These siliceous sandstone soils are considerably improved by the addition of humus, the percentage of which is frequently high on sheltered slopes and in gullies.

In contrast to the shallow soils derived from the sandstones and conglomerates of the lower beds of the Upper Marine Series, the shaly and fine-grained sandstones in the same beds yield a deeper and more loamy soil, with a clayey subsoil. In the Nowra district the latter soil type occurs in patches in the former poorer sandstone soils (see Table 1, lines 1 and 3).

Where the cementing material is calcareous, the sandstone yields a much better soil-type of moderately dark-coloured loam. Soil derived from tuffey sandstones in which lime-felspar partly takes the place of quartz, may be included in this class. Shales and mudstones of a similar composition, which are typical of the Permian series in the Illawarra (Bulli Coal Measures and upper beds of Upper Marine Series) yield a similar soil. Jensen has shown that these loams have a much better proportion of mineral plant-food than the siliceous sandstone soils, and frequently contain quite a high percentage of lime (see Table 1, lines 4-7).

Table No. 1 (compiled from Jensen) gives the averages of a number of analyses of soils described above. In all the tables the figures represent percentages, with the exception of capillarity, which is expressed in inches.

(2) Shale Soils.

The Wianamatta Shales weather to heavy loams or clays, about 8 or 9 inches in depth, with a clayey sub-soil which varies in depth according to the chemical nature of the underlying shales. The basic (ferriferous and calcareous) shales frequently have a dark red-brown coloured friable clay subsoil, about 3 feet in depth. Most of the shales are acid (70% silica) and weather very slowly, so that the sub-soil, which is of stiff yellow clay, averages not much more than 10 inches. These soils are hard and stiff and become saturated in wet weather owing to their impervious nature and lack of sub-drainage. During dry weather they become desiccated and cracked, so that the rise of water by capillarity is prevented. The physiographic and climatic factors increase the physical disadvantages of these soils; the low-lying nature of the country frequently accentuates the lack of

TABLE 1.

Locality.	Geological Series.	Colour.	Water Capacity.	Capillarity.	Clay.	Moisture.	Volatile.	Nitrogen.	Lime.	Potash.	Phosphoric Acid.
Siliceous Sandstones	Nowra	Light ..	30.0	6.0	35.0	3.31	4.37	0.079	0.044	0.038	0.039
	County Cumberland ..	Light. ..	37.9	9.2	18.8	—	7.22	0.133	0.106	0.066	0.137
	Nowra	Light ..	39.0	4.0	53.0	3.7	6.42	0.147	0.055	0.057	0.036
	Ilawarra	Moderately dark ..	—	—	—	4.2	10.20	0.185	0.353	0.127	0.165
Calcareous and Tuffy Sandstones.	Wellongong, Mt. Kiera slopes.	Light brown	48.0	5.0	79.7	5.38	14.43	0.322	0.582	0.213	0.232
	Ilawarra ..										
	Near Mt. Kembla slopes ..	Light grey ..	50.0	8.5	51.0	2.02	6.05	0.126	0.305	0.093	0.132
	Unanderra Flats ..	Dark grey ..	39.0	6.5	85.2	3.95	11.52	0.112	0.510	0.140	0.216

natural sub-drainage, while during drought periods, which are not infrequent, the soil is badly cracked and dried.

The Wianamatta Shale soils are poor in mineral plant-food, as is indicated in the following table, which gives their average analysis calculated from ten soils:

TABLE 2.

Locality.	Water Capacity.	Capillarity.	Clay.	Volatile.	Nitrogen.	Lime.	Potash.	Phosphoric Acid.
Sydney Plains	52.5	5.2	67.7	7.62	0.140	0.136	0.133	0.096

The calcareous ostracod sandstones and shales in the upper beds of the Wianamatta Series yield rich red and chocolate friable clayey soils, containing about 0.5% of lime. These soils occur on the eastern slopes of the Blue Mts. in the vicinity of Kurrajong.

The Narrabeen Shales, which contain volcanic detritus, and the Upper Marine tuffey shales in the Kiama-Nowra district, yield dark, rich, deep and fine-textured loams.

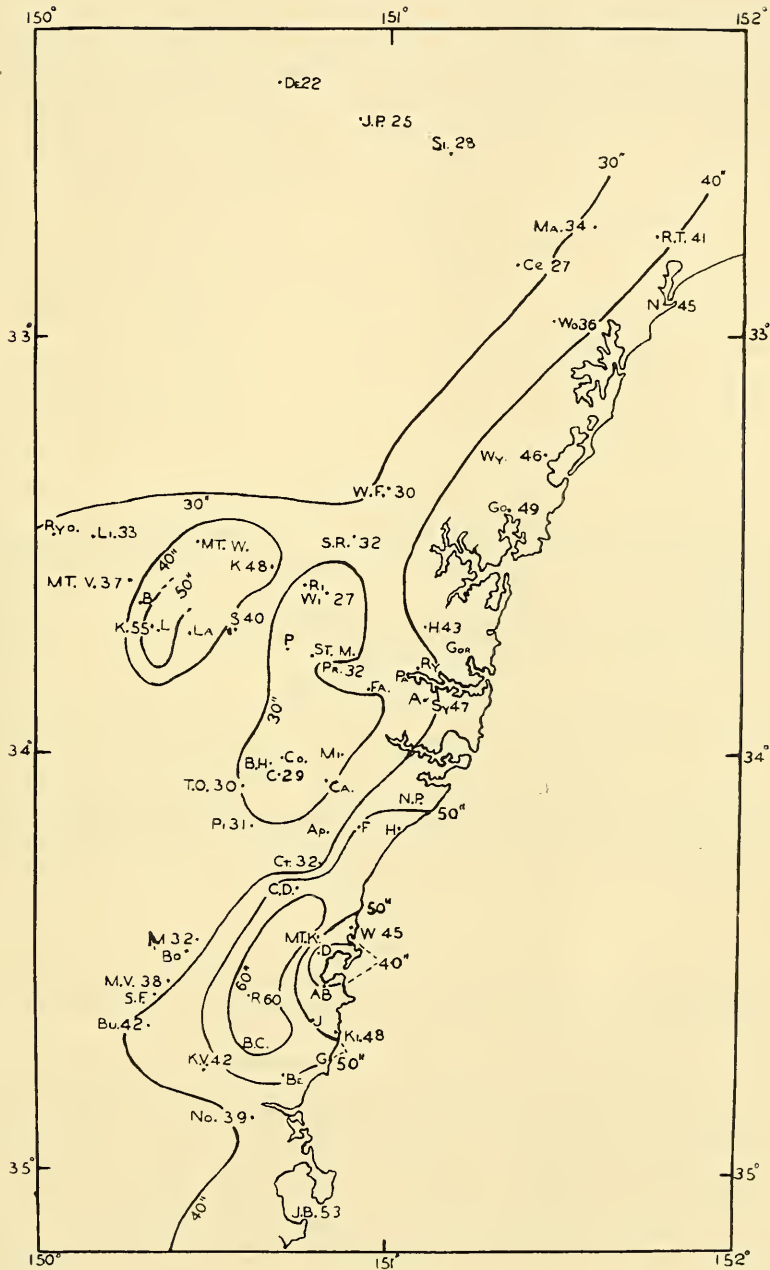
(3) Igneous Soils.

Interbedded with the Illawarra Permian sandstones and mudstones are sills of basalt and beds of tuff which yield very fertile loamy soils, as indicated by Table 3.

The Tertiary trachytes and basalts at Bowral, Moss Vale, etc., yield fairly rich loams. The basalt soils of Mts. Tomah, Hay, etc., are rich in potash, phosphoric acid, magnesia, and lime.

The basalt soils of the Sydney district are of little importance from the

Stations plotted, showing mean annual rainfall (inches) of each, followed by number of years record (in parenthesis): A, Ashfield, 35.4 (35); Ap, Appin, 35.7 (30); AB, Albion Park, 41.1 (41); B, Blackheath, 42.2 (38); Be, Berry, 56.5 (more than 15); Bo, Bowral, 36.7 (51); Bu, Bundanoon, 42.3 (35); B.H., Brownlow Hill, 27.7 (54); BC, Brogers Creek, 76.9 (39); C, Camden, 29.8 (52); Ce, Cessnock, 27.7 (30); Co, Cobbitty, 29 (48); C.D., Cordeaux Dam, 59.3 (64); Ca, Campbelltown, 28.4 (54); Cr, Cataract, 32.7 (53); D, Dapto, 39.6 (24); De, Denman, 22.1 (53); F, Darkes Forest, 59.5 (39); Fa, Fairfield, 32 (6); G, Gerringong, 50.3 (41); Go, Gosford, 49.7 (53); Gor., Gordon, 43 (28); H, Helensburgh, 57.3 (47); J, Jamberoo, 49.3 (more than 15); J.P., Jerry's Plains, 25.1 (49); J.B., Jervis Bay, 53.2 (69); K, Kurrajong, 48.7 (67); Ki, Kiama, 48.3 (38); K.V., Kangaroo Valley, 42.6 (14); L, Leura, 52.4 (23); La, Lawson, 48.6 (41); Li, Lithgow, 33.3 (46); M, Mittagong, 32.7 (34); Mi, Minto, 29.8 (47); M.V., Moss Vale, 38.8 (63); Ma, Maitland, 34.0 (68); MT. K., Mt. Kembla, 60.4 (21); MT. W., Mt. Wilson, 49.3 (more than 15); MT. V., Mt. Victoria, 37.5 (63); N, Newcastle, 45.5 (71); No, Nowra, 39.7 (38); N.P., National Park, 43.3 (26); Pr, Prospect, 32.9 (43); P, Penrith, 29.1 (39); Pa, Parramatta, 35.6 (69); Pi, Picton, 30.9 (56); R, Robertson, 60.5 (46); Ri, Richmond, 29.3 (55); Ry, Ryde, 35.1 (35); Ryd, Rydal, 31.3 (21); R.T., Raymond Terrace, 41.2 (42); S, Springwood, 39.9 (48); Si, Singleton, 28.1 (53); St. M., St. Marys, 27.6 (39); Sy, Sydney, 47.3 (77); S.F., Sutton Forest, 35.5 (32); T.O., The Oaks, 30.3 (24); S.R., Sackville Reach, 32 (27); W, Wollongong, 45.7 (61); Wo, Wollong, 36.7 (45); Wy, Wyong, 46.1 (45); Wi, Windsor, 27.4 (38); W.F., Wiseman's Ferry, 30.6 (18).



Text-fig. 4.—Isohyet map constructed from data supplied by Mr. Mares of the Sydney Weather Bureau and Mr. W. S. Watt, Commonwealth Meteorologist. 30, 40, 50 and 60 inch isohyets shown.

ecological viewpoint owing to their small extent. The numerous dykes and pipes weather much more rapidly than the sandstone or shale, so that they form depressions in the surface. These basalt soils are red in colour and much richer than the shale or sandstone soils. The Prospect dolerite yields a deep chocolate-coloured clayey soil of friable texture due to the high percentage of lime (1-1.5%).

TABLE 3.

Locality.	Geological Type.	Texture.	H ₂ O Capacity	Capillarity	Clay.	Moisture.	Volatile.	Nitrogen.	Lime.	Potash.	Phosphoric Acid.
Kiama hillside..	Bombobasalt.	Heavy loam..	35	6	68.0	8.3	24.65	0.651	0.662	0.234	0.674
Kiama hillside..	Jamberoo tuffs.	Clay ..	56	7	75.7	5.3	12.85	0.238	0.384	0.157	0.137

(4) Alluvial Soils.

The alluvial soils in the Nepean-Hawkesbury area have probably been derived from the adjacent Hawkesbury Sandstone country; they yield similar siliceous sandy loams.

The alluvials of the southern Illawarra are much better soils, since they are of very mixed origin. They vary from heavy to light loams.

(5) Lateritic Soils.

On the Hornsby Plateau, and parts of the Nepean Ramp and Blue Mts., shallow patches of a somewhat lateritic soil-type not infrequently occur on the surface of soils derived from Wianamatta Shales and from Hawkesbury Sandstones. The lateritic nodules are thought to have been formed in the subsoil of the Tertiary peneplain and, by erosion of the upper soil, masses of these "ironstone" nodules, either non-coherent or cemented, have been left on the surface. However, most of these Tertiary podsols are now largely eroded.

Climate.

(1) Rainfall.

From an average of 45 inches on the coastline, the rainfall diminishes to the west, especially in the Sydney Plains, but gradually increases with altitude on the tablelands (see Text-fig. 4).

Thus in the Sydney Plains, the rainfall diminishes to less than 30 inches, so that a low rainfall basin approximately corresponds to this physiographic region. Another interesting feature is that in this area, the Richmond-Windsor district experienced seven dry⁵ years out of a 35-year period, and Picton, Camden, Penrith and Parramatta experienced 5, 4, 3, and 1 dry years respectively, while the surrounding coast and plateau areas were wholly exempt from dry years. The increase with altitude is shown in the Blue Mts., where at Katoomba the mean annual figure is 55 inches, though west from here it again falls to 37 inches at Mt. Victoria.

⁵ Employing a modified classification of Koppen's, Lawrence (1937) has plotted the incidence of individual desert, dry and humid years in N.S.W. for the period 1900-35.

Two important variations occur in the coastal average rainfall in the Illawarra district. These are a dry area near Dapto, where the rainfall falls below 40 inches, and a moist area in the vicinity of Kiama extending inland to Robertson, where an average of 60 inches is obtained. These variations have a marked effect on the vegetation.

The following mean monthly and annual figures⁶ indicate the variation in the amount and distribution of the rainfall received over the central coastal area. A double maximum is characteristic (see Text-fig. 5).

TABLE 4.

Station.	Height* Above Sea- Level, Ft.	No. of Yrs. Record.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year Points.
Sydney	67	77	357	426	486	550	512	472	486	287	291	286	284	295	4,732
Parramatta	50	69	342	356	402	350	293	284	347	205	218	233	240	291	3,561
Penrith	89	39	278	286	294	274	213	186	293	154	178	199	240	322	2,917
Windsor	51	38	270	256	267	280	229	180	275	161	170	178	217	266	2,749
Camden	222	52	335	253	322	286	218	249	286	156	166	192	229	291	2,983
Picton	552	56	328	292	337	306	227	240	261	155	192	230	228	300	3,096
Springwood	1,218	48	420	452	500	382	276	264	296	193	260	252	325	372	3,992
Katoomba	3,336	50	593	649	633	520	392	441	456	307	324	311	382	527	5,535
Mt. Victoria	3,424	63	357	418	377	329	287	310	324	219	249	250	292	343	3,755
Hornsby	594	12	316	450	434	641	382	343	379	147	277	270	343	372	4,354
Wollongong	56	61	445	468	468	539	447	408	393	227	284	267	273	358	4,577
Robertson	2,427	46	581	543	670	549	517	582	649	376	394	362	328	504	6,055
Bowral	2,210	51	371	306	376	322	291	343	386	220	230	232	252	346	3,675
Nowra	26	38	396	339	339	392	424	355	420	238	245	250	223	349	3,970

* The height given is that of the local railway station.

At Sydney, the evaporation rate exceeds precipitation during the late spring and early summer months (October to January inclusive), which are thus relatively dry. This is shown in the following table.

TABLE 5.

	No. of Yrs. Record.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Evaporation points	56	538	424	365	261	183	144	153	194	271	390	462	539	3,930
Rainfall points	77	357	426	486	550	512	472	486	287	291	286	284	295	4,732

(2) Winds.

The south-east and north-east winds are responsible for most of the rainfall over the area.

⁶ I am indebted to Mr. Mares, of the Weather Bureau, Sydney, for meteorological data.

The westerlies are prevailing winds during the autumn, winter and early spring months, as is shown in Table 6. These are desiccating in summer, cold in winter. Throughout the central coastal area, wherever the topography permits the comparison of easterly and westerly facing slopes, the influence of westerly winds on the vegetation becomes obvious. The effect is particularly marked in the Blue Mts. and Hornsby Plateau where the forests are frequently replaced by scrub or scrub-forests in habitats exposed to westerly winds. Onshore winds exert a similar influence in that they stunt the vegetation of the coastal headlands (Pl. xvi, fig. 5).

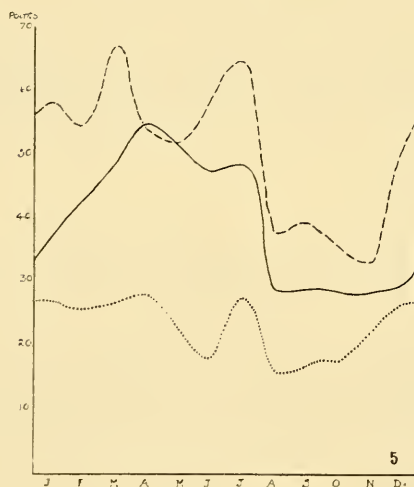
Table 6 shows the prevailing direction of winds for Sydney at 9 a.m. and 3 p.m., expressed as monthly averages over a period of 69 years.

TABLE 6.

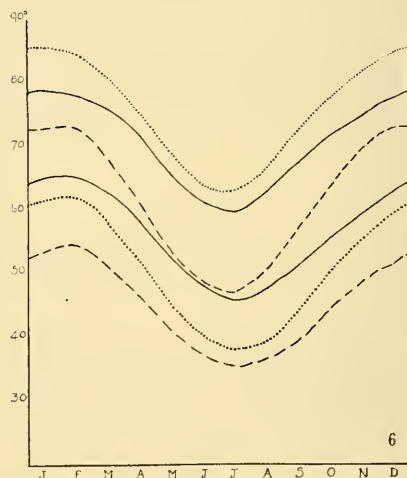
Prevailing Direction.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.
9 a.m. . . .	NE	NE	W	W	W	W	W	W	W	W	ENE	ENE
3 p.m. . . .	ENE	ENE	ENE	ENE	NE	W	W	NE	NE	ENE	ENE	ENE

(3) Temperature.

Extremes of temperature are infrequent on the coast, but on the Sydney Plains and at high altitudes on the plateaux the range is considerable; the mean daily range at Sydney is 14 F. degrees, compared with 25 F. degrees at Richmond, 26 F.



Text-fig. 5.—Graph showing the mean monthly rainfall at Robertson (broken line), Sydney (unbroken line), and Windsor (dotted line).



Text-fig. 6.—Graph showing the mean maximum and minimum monthly temperature at Richmond (dotted line), Sydney (unbroken line), and Mt. Victoria (broken line). At each station the uppermost line represents the mean maximum reading.

degrees at Picton and 23 F. degrees at Bowral. On the plateaux the winter temperatures are much lower than on the coast, and snow frequently falls. The average annual temperature for the whole area is approximately 63° F.

Table 7 gives the mean monthly maximum and minimum temperatures at different localities (see also Text-fig. 6).

TABLE 7.

Station.	No. of Yrs. Record.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Sydney—														
Mean max. °F. ..	73	78.4	77.7	75.7	71.3	65.5	61.1	59.8	62.8	67.0	71.3	74.4	77.1	70.2
Mean min. °F. ..	73	64.9	65.0	62.9	58.1	52.2	48.3	45.9	47.5	51.4	55.8	59.6	62.9	56.2
Parramatta—														
Mean max. °F. ..	16	83.0	81.8	79.5	74.9	68.8	64.1	62.6	66.2	71.6	75.3	79.4	82.3	74.1
Mean min. °F. ..	16	62.0	61.9	58.2	53.0	47.2	42.8	41.2	41.7	46.8	51.3	56.4	60.4	51.9
Wollongong—														
Mean max. ..	57	79.2	78.7	76.8	72.6	67.1	62.7	61.8	64.4	68.6	72.4	65.1	77.6	71.4
Mean min. ..	57	62.3	62.6	60.4	56.3	51.3	47.8	46.0	47.0	50.4	53.7	57.1	60.4	54.6
Richmond—														
Mean max. ..	24	85.2	84.2	80.6	74.8	68.6	63.6	63.0	66.2	72.2	77.3	81.7	84.5	75.2
Mean min. ..	24	61.6	62.0	57.9	51.8	44.9	40.1	38.0	39.5	44.4	50.4	55.3	59.6	50.5
Picton—														
Mean max. ..	24	85.4	84.1	80.5	75.0	68.1	62.9	61.9	65.1	71.0	75.8	80.1	83.6	74.5
Mean min. ..	24	59.6	60.2	54.9	48.9	42.7	38.4	36.4	37.3	41.7	47.8	53.2	57.9	48.2
Bowral—														
Mean max. ..	21	79.4	79.2	74.2	67.1	59.9	53.9	53.1	56.8	63.5	70.0	75.9	78.9	67.7
Mean min. ..	21	54.3	55.1	51.6	44.9	40.0	36.1	34.6	36.1	40.8	44.7	48.9	52.3	44.9
Mt. Victoria—														
Mean max. ..	19	72.8	72.9	67.8	60.7	53.1	48.5	47.0	50.6	57.2	63.6	69.6	72.7	61.4
Mean min. ..	19	53.3	54.6	51.0	46.4	41.0	37.4	35.4	36.5	39.8	44.5	48.6	51.3	45.0

(4) Relative Humidity.

Table 8 shows the relative humidity values for several different localities in the area. Figures are not available for local variations such as occur in different topographical habitats, e.g., in moist gullies sheltered from wind and sun there is a definite micro-climate characterized by high atmospheric humidity. Such conditions are important in that they favour the development of rain-forest species.

TABLE 8.

Station.	No. of Yrs. Record.	January	February.	March.	April.	May.	June.	July.	August	September.	October.	November	December.	Year.
Sydney	73	67	71	72	76	78	78	76	72	66	63	63	64	70
Wollongong ..	23	75	76	76	76	75	76	75	71	68	69	69	73	73
Parramatta ..	16	63	69	70	73	76	77	75	68	63	59	58	61	68
Richmond ..	24	64	69	70	75	79	80	76	71	63	60	59	61	69
Mt. Victoria..	20	71	74	75	77	79	82	83	75	66	65	63	67	73

(5) Sunlight.

The intense sunlight is a feature of the climate, and is partly responsible for the sclerophyllous nature of the plants. Table 9 gives the mean monthly hours of sunshine over a period of 15 years at Sydney.

TABLE 9.

	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Year.
Mean hours of sunshine.	229.2	206.2	201.3	184.4	174.8	158.2	186.3	221.4	218.3	240.3	230.6	225.3	2476.3

The amount of sunlight received in any area depends on the topography; open undulating country and the tops of ridges and uplands receive the maximum amount, while valley floors and slopes, especially south and south-east slopes, are in shadow part of the day. Direct sunlight penetrates the canopy of *Eucalyptus* forests, but reaches the ground in rain-forests only through occasional light breaks.

Biotic Factors.

Much of the vegetation of the central coastal area has been disturbed or entirely cleared since the advent of settlement. Most of the coastal rain-forests have been partially cleared owing to the economic value of one of its trees, *Cedrela australis* F.v.M., whilst other patches on volcanic soil have been cleared for dairy farms. Since the best timber and soils in this area are found in the coastal plains, especially in the Illawarra, partial clearing and selective cutting were inevitable. However, patches of relatively undisturbed forests on the foothills of the scarp and elsewhere, and isolated trees occurring throughout the plains, are sufficient indication of the original vegetation.

The Sydney Plains have been extensively cultivated and used for pastoral purposes for nearly 150 years, so that it is not surprising that most of the vegetation in this area has been disturbed (Pl. xvi, fig. 1).

Except in areas of urban extension, the Hawkesbury Sandstone flora is relatively undisturbed by man. As a result of settlement, however, bush fires are of annual occurrence, and in some seasons very extensive areas of the flora are damaged. There are several large reserves: Kuring-gai Chase in the Hornsby Plateau and the Catchment Area in the Nepean Ramp.

THE VEGETATION.

As previously stated, the two plant-formations occurring in the area are sub-tropical rain-forest and *Eucalyptus* forest. The forests, even before clearing, did not form a continuous cover, patches of seral vegetation occupying a few areas, such as coastal dunes and wind-blown sands, swampland, scrubland, etc.

Sub-tropical Rain-Forest.

These forests, locally known as "brush", although now present only as depauperate remnants, once covered the slopes and valleys of the Illawarra from Bulli to Berry, growing on the loams derived from the Permian rocks, and on the rich basaltic soils. Rain-forest also extended to the basalts at Robertson

(see p. 329). Throughout the whole of the Illawarra plain relics of rain-forest are now practically restricted to creek banks and valleys in the foothills (Pl. xvi, figs. 7, 8), but the widespread occurrence of the Cabbage-tree Palm, *Livistona australis* Mart., which is a typical component of rain-forest in this area, indicates a former extensive distribution (Pl. xvii, fig. 9). One of the largest remnants occurs on the lower slopes of the Illawarra scarp at Bulli, chiefly on Narrabeen Shales and Upper Coal Measures.

Remnants of sub-tropical rain-forest also occur on the chocolate shales in the Gosford district, particularly in the shelter of valleys; and as a fringing forest along Bola Creek, National Park, on the same formation.

On the basalt residuals of Mt. Wilson (Brough, McLuckie and Petrie, 1924), Mt. Tomah, etc., and in the valleys of the Blue Mts. (Pl. xvii, fig. 10), a poorer type of rain-forest occurs. It is not so rich floristically as the sub-tropical rain-forest, and has an admixture of sclerophyll types. Fraser and Vickery (in MS.) refer to this as impure sub-tropical rain-forest. The latter also occurs, to a minor extent, in a few of the coastal gorges, usually where Narrabeen Shales outcrop. These habitats have a definite micro-climate, in that they are sheltered from winds and extreme insolation, and relative humidity and soil-moisture conditions are favourable.

At Grose Vale, a sheltered habitat on the eastern scarp of the Blue Mts., remnants of rain-forest occur on the ostracod soils of the Wianamatta Series, but are now so damaged that it is impossible to ascertain their original floristic composition.

It is obvious that, in the central coastal area, rain-forest is typical of the better class soils receiving a moderately high rainfall. Its absence from parts of the basalt at Mt. Wilson is attributable only to exposure. In the development of rain-forest, high soil-moisture content is more important than chemical composition of the soil, as illustrated at Mt. Wilson, where rain-forest is absent from exposed basalt-soils, but occurs in the shelter of the Hawkesbury Sandstone valleys. The sandstone soils are here enriched by basalt wash, and have a fairly high humus content. It is interesting to note, however, that on sandstone the floristic composition of the impure sub-tropical rain-forest contains a stronger admixture of sclerophyll types than that occurring on the better soils.

In favourable habitats on the sandstone, hardier marginal rain-forest species are frequently admixed with sclerophyllous types to form a true ecotone.

Eucalyptus Forest.

(1) General Structure.

This is essentially a sclerophyll forest of tall-growing *Eucalyptus* trees, but the average height varies from 30 feet to more than 200 feet, according to habitat conditions. The canopy is usually continuous, but differs from that of rain-forests in being much thinner. Thus a considerable amount of sunlight penetrates to the ground; this feature is accentuated by the pendent nature of *Eucalyptus* leaves. The undergrowth forms a continuous ground-cover except on sandstone formations, where it is interrupted by extensive outcrops of rocks and boulders. In typical *Eucalyptus* forests, the undergrowth may be said to consist of a continuous ground-cover of herbs and grasses, with a scattered assemblage of shrubs. The shrubs most frequently form two interrupted layers. The low shrubs may be considered as those not exceeding 6 feet, and averaging about 3-4 feet; the tall shrubs are usually under 12 feet. The shrub strata vary considerably in density from



abundant and continuous to scanty and discontinuous, and frequently form local thickets. Generally speaking, smaller shrubs are more abundant.

The variations in the undergrowth are largely controlled by edaphic and climatic factors; e.g., in the sandstone forests a shrubby undergrowth predominates, whilst the forests typical of Wianamatta Shale are characterized by an herbaceous ground-cover. Elsewhere, more specific habitat factors, such as topography, degree of shelter, and moisture, are chiefly responsible for variations in the undergrowth, e.g., sclerophyll shrubs are most abundant in habitats exposed to greatest insolation, such as plateau surfaces, whilst moisture- and shade-preferring shrubs and herbs are abundant along creek banks and gully slopes, etc.

(2) The Associations.

Following Clements' system of classification, many distinct associations are recognized within the *Eucalyptus* forest formation. Those present in the central coastal area are mentioned below. Two of these, the Mixed *Eucalyptus* Forest Association and the *E. hemiphloia*-*E. tereticornis* Association are typical of, although not confined to, the central coastal region; the others are interpreted as local expressions of associations more widely distributed elsewhere.

Mixed *Eucalyptus* Forest Association.

The Mixed *Eucalyptus* Forest Association is typical of sandy-loam soils derived from the Hawkesbury Sandstones, Upper Marine sandstones and certain sandstones in the Newcastle Coal Measures. This association is almost limited to the central coastal area, although local expressions of it occur further south.

It is a distinctive and unique association, differing from most of the coastal forests in its extremely low integration. It is characterized by a large number of dominants in any one stand, and a well developed scrubby undergrowth. Several of the dominant tree species range throughout the association whilst others are limited by such factors as latitude and altitude. In the coastal districts, the most important trees are *Eucalyptus haemastoma*, *E. micrantha*, *E. piperita*, *E. Sieberiana*, *E. eugenoides*, *E. gummifera*, *Angophora lanceolata*, *E. pilularis* and *E. punctata*. At higher elevations (Blue Mts. and Moss Vale) the last four species are absent or unimportant, whilst other species occurring in this association are restricted to these areas, e.g., *E. radiata*, *E. maculosa*, *E. Blaxlandi*, *E. oreades*, etc.

This forest association frequently merges into a "scrub-forest" in which the stand of timber averages only 30-40 feet and is rather more open than in typical forests, whilst the growth of shrubs is correspondingly greater. Scrub-forest is of frequent occurrence on the uplands of the Blue Mts. and Hornsby Plateau (Pl. xvi, fig. 4), as a result of exposure to strong westerly winds and insufficient soil-water reserve. In the most unfavourable of these areas the forest is entirely replaced by a low-growing scrub or heath.

The tallest forest communities in this association attain a height of 80 feet or more and occur on slopes and in gullies where conditions of soil moisture, soil depth, shelter, temperature and humidity are most favourable.

Although this forest association occurs in areas receiving moderately high rainfall, the soil conditions are unfavourable in that, as well as being poor in mineral plant-foods, the sandy, shallow and porous soils are frequently excessively drained. On the other hand, on level areas on the plateaux the drainage is often deficient, and these habitats are characterized by a type of swamp vegetation,

⁷ Authorities for *Eucalyptus* spp. mentioned in this paper are recorded in the appendix.

especially well-developed west of Bulli where the plateau is not dissected (Davis, 1936).

Following Clements' system of naming the association after the two most widely distributed and characteristic dominants, Petrie (1925) suggested the tentative nomenclature of *E. piperita*-*E. haemastoma* var. *micrantha* for this association as it occurs in the vicinity of Mt. Wilson. He also pointed out that this term would be inadequate when the association was studied more widely. This has proved to be so, and by reason of the large number of widely distributed dominants, it has been found impossible and undesirable to attempt to name this association by two species. It seems more desirable that the name used should imply a variety of dominants, hence this unit is referred to as the Mixed *Eucalyptus* Forest Association.

According to the system of classification adopted here, the *E. Sieberiana*, *E. piperita* and *E. pilularis* associations described by Davis (1936), rank only in the nature of consociations within the more extensive and more widely distributed Mixed *Eucalyptus* Forest Association. Davis is here using the term association in a smaller sense of the word.

The *Eucalyptus hemiphloia*-*E. tereticornis* Association.

This association characterizes the Wianamatta Shale soils in the low-rainfall basin of the Sydney Plains. Another fragment occurs in the Dapto district (Illawarra) on Permian shales (see page 329).

The vegetation of the Sydney Plains has been converted by partial clearing into a park land or open savannah woodland, with a ground cover of pasture grasses, partly native and partly exotic. However, from remnants of the original vegetation, and from natural secondary growths, it seems fairly certain that the area was originally thinly forested. In the driest areas at least, the *E. hemiphloia*-*E. tereticornis* association probably approached a woodland tree-spacing. This association may be interpreted as an ecotone community showing structural features intermediate between the savannah woodland and *Eucalyptus* forest formations. This interpretation is supported by a consideration of the climatic conditions, since the average rainfall figures for the Sydney Plains approximate more to those of the western slopes than the coastal area.

The original undergrowth in the *E. hemiphloia*-*E. tereticornis* association probably consisted of a large percentage of grasses and herbaceous types, and possibly a number of geophytes with relatively few shrubs. In the regeneration of the undergrowth after clearing, the dominance of native pasture grasses is most marked. *Bursaria spinosa* Cav. is a shrub which is apparently well adapted to the habitat conditions, as it is an almost constant species in regenerating areas.

In the Sydney Plains, the dominant trees of this association are *Eucalyptus hemiphloia*, *E. tereticornis*, *E. siderophloia*, *E. sideroxylon*, *E. crebra*, *Angophora intermedia* and *A. subvelutina*.

E. hemiphloia forms a consociation characteristic of the drier parts of the association, this species being apparently especially tolerant of alternating soil conditions of desiccation and water-logging.

The *E. tereticornis* consociation represents a slightly moister phase in this association, and thus is more frequent than *E. hemiphloia* in the Illawarra.

The *E. maculata*-*E. paniculata* Association.

Eucalyptus maculata occurs in this area as a consociation on shaly sandstone soils, chiefly of the Upper Marine Series in the Nowra district. It is often pure (Pl. xvii, fig. 11), but in the Nowra district is frequently associated with

E. paniculata and *E. pilularis*, and also with *E. micrantha* and *E. gummifera* in the more sandy areas. Fragments of the *E. maculata* consociation occur on the light alluvials in the Illawarra. This consociation is also found as an ecotone community between the mixed *Eucalyptus* forest and the *E. hemiphloia*-*E. tereticornis* association, where the soil is a mixture of shale and sandstone. It also reappears in the vicinity of Lake Macquarie on the sandy shales of the Coal Measure and Narrabeen Sandstones. It is present on the latter formation on the foreshores of Pittwater (Broken Bay).

When not occurring in almost pure stands, *E. maculata* is most frequently associated with various species of Ironbark, such as *E. paniculata* in the Bateman's Bay district, south of the central coastal area, *E. crebra* in the Hunter River Valley, and *E. siderophloia* in the Brisbane district, Queensland. Thus *E. maculata* may be tentatively regarded as belonging to the *Eucalyptus maculata*-*E. paniculata* Association.

The *E. saligna*-*E. pilularis* Association.

This association is typical of the well-watered loams on the coastal plains. It is one of the most widespread coastal associations. In this area *E. saligna* is best represented on the rich loams derived from the Narrabeen Shales, i.e., in the northern Illawarra and north of the Hawkesbury River. On these loams in the Illawarra, *E. saligna* is associated with *E. quadrangulata*, both of which extend into the rain-forest. North of the Hawkesbury, *E. Deanei* (Pl. xvii, fig. 12) and *E. acmenioides* frequently occur with *E. saligna*. *E. pilularis* occurs throughout the coastal plains either as a dominant, or co-dominant with *E. saligna*. Another fairly widespread species is *Syncarpia laurifolia*. *E. paniculata* (Pl. xvii, fig. 13) also occurs, but is not abundant in this association.

On the valley slopes in the Blue Mts., merging into rain-forest, the association is represented by a community of *Syncarpia laurifolia*, *Casuarina torulosa*, *Angophora intermedia* and *E. Deanei*.

In valleys in the coastal area and Blue Mts., the sub-dominants occurring in this association are moisture-preferring and may include ferns, tree-ferns, and a few of the hardier rain-forest species. This type of forest has been referred to as wet sclerophyll forest. It frequently occurs around the margins of rain-forest.

Although *E. pilularis* occurs in wet sclerophyll forest, it is also present in drier habitats and on lighter loams than those supporting *E. saligna*. In such habitats, *E. pilularis* is often associated with *E. paniculata*.

The *E. saligna*-*E. pilularis* Association is widespread in the northern parts of the coast of New South Wales. Important species here are *E. grandis* and *E. microcorys*. The latter occurs at Lake Macquarie, in the central coastal area, which is about its southernmost range.

The *E. viminalis*-*E. obliqua* Association.

The widely distributed *E. viminalis*-*E. obliqua* Association, which is characteristic of the cool tablelands throughout the coast of south-eastern Australia, occurs in small patches at high elevations in the central coastal tablelands. The *E. goniocalyx*-*E. Blarlandi* association described by Petrie (1925) and Petrie and McLuckie (1926) at Mt. Wilson, is interpreted as a local expression of the larger *E. viminalis*-*E. obliqua* Association.

At Moss Vale and Robertson the chief species belonging to this association are *E. obliqua*, *E. fastigata* and *E. Lindleyana*. They occur on fairly good loams, partly derived from basalts on the uplands, but this association also extends into the valleys. At Bowral, *E. viminalis* is typical of the soils derived from trachytes.

In the Blue Mts., *E. riminalis* occurs on the basalts and in the valleys, whilst *E. fastigata* is also present in the valleys. *E. goniocalyx* occurs on the basalt-capped areas with *E. riminalis*, but is typical of light sandy loams in the upper parts of the valleys. In the drier western section of the Blue Mts., *E. rubida* and *E. dives* represent the association. *E. Smithii* is another species belonging to this association and is typical of the warmer and moister tableland area bordering the Illawarra.

The *E. pauciflora*-*E. stellulata* Association.

The *E. pauciflora*-*E. stellulata* Association, which characterizes the areas of the tablelands approaching sub-alpine conditions, is represented in the locality west of Moss Vale. Here, these two species are associated with *E. radiata*. These forests are rather low-growing and open in structure, and approach more to the woodland than forest formation.

Consociations, or, more strictly speaking, consocieties, which are typical of the coastal plains and occur throughout the whole of the *Eucalyptus* forest formation, are *E. amplifolia* (Pl. xvii, fig. 14) and *E. robusta*. *E. amplifolia* is typical of freshwater swampy flats, frequently on heavy soils. *E. robusta* forms a typical hind-swamp or lagoon forest on the coastline. It is often associated with *E. botryoides*.

Minor Vegetation Types.

These are chiefly in the nature of seral communities or relatively permanent vegetation types induced by unfavourable habitat conditions. In the latter category are scrubs and swamps in upland areas.

Low-growing scrub or heath vegetation has already been mentioned in connection with the Mixed *Eucalyptus* Forest Association, in which it occurs on shallow porous sandy soil on ridges and uplands exposed to westerly winds. A similar type of scrub occurs on the coastal headlands (Pl. xvi, fig. 5) where the stunting of the vegetation is caused by strong onshore winds.

On the uplands in badly-drained areas, due either to the nature of the underlying rock or to the configuration of the local topography, a swamp vegetation persists as the climax of a deflected succession. The plants composing the swamp are low-growing sedge-like plants, many of which are hemicyptophytes, and a few shrubs. A particularly large swamp, known as the Wingecarribee, occurs in the district west of Robertson. Relatively smaller swamps are typical of, and occur scattered over, the sandstone uplands.

Of the seral communities, the most important are the successional phases initiated on sand-dunes, in salt-water (Collins, 1921) and fresh or brackish water, all of which culminate in *Eucalyptus* forest.

The seral phases of the psammosere are well known as the strand flora, the sand-binding grasses, the hummock-building mat chamaephytes and the dune scrub passing into *Eucalyptus* forest. The earliest stages of this succession are found on almost every beach, but the hind-dune forests are generally very disturbed as a result of settlement.

The hydrosere initiated on mud flats of the salt-water estuaries of Port Jackson, the Hawkesbury River, etc., are characteristically zoned in the following sequence: Mangroves, *Salicornia* salt meadow, grass meadow, rush meadow, *Casuarina* swamp forest and *Eucalyptus* forest.

The zonation occurring on the margins of lagoons or other fresh or brackish water consists of submerged and floating communities, amphibious and emerged

communities of rush and sedge meadows, and finally, as before, *Casuarina glauca* forest which here passes into a swamp forest of *E. robusta* and *E. botryoides*.

CONCLUSIONS.

Sub-tropical rain-forest can be regarded as a post-climax formation (Clements, 1916, 1936) whilst the *Eucalyptus* forest formation is the climatic climax of the coastal area.

In the delimitation of the *Eucalyptus* forest associations in the central coastal area, it is evident that the edaphic factor is the most important. At the same time, individual species have a fairly wide range of soil types and habitats. One such species is *E. pilularis* which is an important member of the Mixed *Eucalyptus* Forest, the *E. saligna*-*E. pilularis* and the *E. maculata*-*E. paniculata* Associations.

Under nearly identical climatic conditions, soil type differentiates the following associations: Mixed *Eucalyptus* Forest, *E. saligna*-*E. pilularis* and *E. maculata*-*E. paniculata*. Sub-climatic rather than edaphic factors control the distribution of the *E. pauciflora*-*E. stellulata* and *E. riminalis*-*E. obliqua* Associations, while a combination of both factors controls the development of the *E. hemiphloia*-*E. tereticornis* Association.

Two of the most extensive associations in the area show features which are peculiar when compared with the rest of the *Eucalyptus* Forest formation. The *E. hemiphloia*-*E. tereticornis* Association, by reason of its habitat conditions, is not a true forest throughout its extent, but shows features intermediate between the coastal forests and woodlands of the western slopes.

The Mixed *Eucalyptus* Forest Association, owing to its low integration and general expression as a "scrub-forest", is also differentiated from the typical coastal forests. Following Clements' system of terminology, this vegetation type would be classified as an associes. It is preferably interpreted in the nature of an edaphic climax in the sense of Tansley (1935), since it is in an apparently permanent condition and "in equilibrium with all the incident factors", the most important of which is the unfavourable edaphic factor.

Within this edaphic climax sandstone vegetation, there is a series of physiographic climaxes which represent the successional development. This aspect will be discussed in a subsequent paper.

SUMMARY.

As an introduction to a series of papers on the ecology of the central coastal area, the general environmental features are discussed as geological, physiographic, edaphic, climatic and biotic factors.

A general description of the vegetation is given. Two plant formations are recognized: Sub-tropical rain-forest and *Eucalyptus* forest. The former is a post-climax coastal vegetation type, while the latter is the climatic climax formation of the coast and tablelands of New South Wales.

The conditions controlling the development of rain-forest are high soil-moisture, a certain degree of shelter, and a moderately good soil, so its occurrence is necessarily restricted.

The ecological features of the sub-tropical and impure sub-tropical rain-forests occurring in this area are not included here, since Fraser and Vickery (1937 MS, a, b) discuss their structural characteristics and general floristic composition.

The various types of *Eucalyptus* forest occurring in the central coastal area are classified as associations according to Clements' system, but with a slightly modified nomenclature including Tansley's conception of climax communities.

Of the associations recognized, the Mixed *Eucalyptus* Forest and the *E. hemiphloia*-*E. tereticornis* Associations are typical of the central coastal area. The others, namely, the *E. saligna*-*E. pilularis*, *E. maculata*-*E. paniculata*, *E. viminalis*-*E. obliqua* and *E. pauciflora*-*E. stellulata* Associations, are only local expressions of much more widely distributed associations. *E. robusta* and *E. amplifolia* are consociations occurring throughout the coastal belt and not limited to any one association.

Fraser and Vickery (1937 MS, b) discuss the *E. saligna*-*Syncarpia laurifolia*, *E. hemiphloia*-*E. tereticornis*, *E. viminalis*-*E. obliqua* and *E. pauciflora*-*E. stellulata* Associations in the Barrington Tops district.

Davis (1936) has also recorded a local expression of the *E. saligna*-*E. pilularis* Association, but he refers to the consociations as two separate associations.

At Mt. Wilson, Petrie and McLuckie (1925-6) have also recorded the *Eucalyptus* Forest Association and the local expression of the *E. viminalis*-*E. obliqua* Association.

These records from different localities indicate the fragmentary nature of the coastal *Eucalyptus* Forest Associations.

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Appendix.

<i>Angophora intermedia</i> DC.	<i>Eucalyptus grandis</i> Maiden	<i>Eucalyptus punctata</i> DC.
<i>lanceolata</i> Cav.	<i>gummifera</i> Gaertn.	<i>quadrangulata</i> Deane and
<i>subvelutina</i> F.v.M.	<i>haemastoma</i> Sm.	Maiden
<i>Casuarina torulosa</i> Ait.	var. <i>micrantha</i> DC.	<i>radiata</i> Sieb.
<i>Eucalyptus acmenioides</i>	<i>hemiphloia</i> F.v.M.	<i>robusta</i> Sm.
Schau.	<i>Lindleyana</i> DC.	<i>rubida</i> Deane and Maiden
<i>amplifolia</i> Naudin.	<i>maculata</i> Hook.	<i>saligna</i> Sm.
<i>Blaxlandi</i> Maiden and	<i>maculosa</i> R. T. Baker	<i>siderophloia</i> Benth.
Cambage	<i>micrantha</i> DC.	<i>sideroxyylon</i> Benth.
<i>botryoides</i> Sm.	<i>microcorys</i> F.v.M.	<i>Sieberiana</i> F.v.M.
<i>crebra</i> F.v.M.	<i>obliqua</i> L'Her.	<i>Smithii</i> R. T. Baker
<i>Deancei</i> Maiden	<i>oreades</i> R. T. Baker.	<i>stellulata</i> Sieb.
<i>dives</i> Schauer	<i>paniculata</i> Sm.	<i>tereticornis</i> Sm.
<i>eugenioides</i> Sieb.	<i>pauciflora</i> Sieb. (= <i>coriacea</i>	<i>viminalis</i> Labill.
<i>fastigata</i> Deane and	A. Cunn.)	<i>Syncarpia laurifolia</i> Ten.
Maiden	<i>pilularis</i> Sm.	
<i>goniocalyx</i> F.v.M.	<i>piperita</i> Sm.	

EXPLANATION OF PLATES XVI-XVII.

Plate xvi.

- 1.—Sydney Plains, looking south from Grose Vale. The monocline of the Blue Mts in the distance.
- 2.—A tributary valley of the Kangaroo River showing canyon formation. Mixed *Eucalyptus* scrub-forest on top of sandstone cliffs at left.
- 3, 4.—Typical country in the Hornsby Plateau. Fig. 4 shows scrub-forest of mixed *Eucalyptus* Forest Association in middle-ground, semi-swamp vegetation in foreground.
- 5.—Coastline of sandstone headlands alternating with short sandy beaches, between Port Hacking and Stanwell Park.
- 6.—Narrow coastal plain, Stanwell Park, Illawarra.
- 7.—Illawarra scarp and foothills with plains in left distance, Berry District, looking south. Chiefly rain-forest vegetation.
- 8.—Remnants of sub-tropical rain-forest on foothills at Kiama, Illawarra.

Plate xvii.

- 9.—South Coastal plain, Milton. Cleared land with *Livistona australis* as remnant of rain-forest. Secondary growth of *Eucalyptus* spp. in middle background

- 10.—Valley in the Blue Mts. showing a creek community of *Todea barbara* with rain-forest in left background.
- 11.—Forest of *E. maculata*, chiefly secondary growth. Nowra, Illawarra.
- 12.—High forest of *E. Deanei* with an admixture of mesophytic sub-dominants, Mooney Mooney Creek, Hawkesbury River.
- 13.—Stand of *E. paniculata* with *Macrozamia* sp. and ground stratum of *Imperata cylindrica* var. *Koenigii*, north of Sydney.
- 14.—*E. amplifolia* with shrub stratum of *Melaleuca* sp., swampy flats, Nowra.

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